Physical and Biological Effects on Tide Flat Sediment Stability and Strength – Phase 2

Robert A. Wheatcroft
College of Oceanic and Atmospheric Sciences
Oregon State University
Corvallis, OR 97331
phone: (541) 737-3891 fax: (541) 737-2064 email: raw@coas.oregonstate.edu

Award Number: N00014-10-1-0248

LONG-TERM GOALS

The ultimate goal of this research is to better understand the physical and biological processes that control the erosion, transport and deposition of fine-grained sediment in marine environments by collecting high-resolution field data that is compared to simple conceptual models.

OBJECTIVES

This research is part of the Tidal Flats Department Research Initiative (DRI) that (amongst other goals) is focused on understanding the controls of sediment strength over multiple time and space scales on the mudflats of Willapa Bay, Washington. My role in the DRI is to: (1) obtain high-resolution profiles of sediment bulk density to compare against erodibility measured by other investigators, and (2) collect time series data on near-surface porosity, as well as seagrass abundance, surficial particulate organic carbon content, and chlorophyll-*a* concentration. The latter are both proxies of exopolymeric substances (EPS), which are known to affect sediment erodibility.

APPROACH

The general approach in the DRI has been to exploit the strong seasonality in physical forcing that exists on the Willapa Bay mudflats to better understand sediment erosion and deposition and the development of seabed strength. Thus, we focused initially on making measurements during two parts of the year (March vs. July) that have important differences in key forcing variables (e.g., solar insolation, rainfall, wind waves, seagrass cover). Measurements have been mostly focused in and around a secondary, 5-m wide channel ("C-channel") that drains a portion of the Willapa Bay mudflat. There, a series of stations have been occupied on the adjacent flats (B and C) and at various points across and along the channel itself. Recognizing that it is difficult to clearly understand seasonality effects with only two time points, I expanded my sampling effort to include more frequent (~6 week intervals) visits to the study region over an entire year. In addition, to better understand small-scale spatial variability (which our previous measurements and observations suggested was potentially important), I included seabed sampling of the mudflats when they were emergent.

My efforts have been focused on acquiring a high-resolution data set on seabed strength using an in situ resistivity profiler and collecting time-series data on important physical (e.g., rainfall, temperature,

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2011**	2. REPORT TYPE	3. DATES COVERED **00-00-2011 to 00-00-2011**

4. TITLE AND SUBTITLE **Physical and Biological Effects on Tide Flat Sediment Stability and Strength - Phase 2**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Oregon State University,College of Oceanic and Atmospheric Sciences,Corvallis,OR,97331**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**4**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

insolation) and biological forcings (e.g., chlorophyll *a*, seagrass). In particular, co-located measurements of sediment porosity and erodibility using a portable In situ Resistivity Profiler (IRP, Wheatcroft, 2002) and a Gust chamber (Stevens et al., 2007; Wiberg et al., in review), respectively, have been made at a variety of stations. By coupling the erodibility results to the much more easily obtained porosity data, it has been possible to map seabed erodibility over larger spatial domains, which is a necessary first step toward initializing and testing models of tide flat morphology. In addition to the porosity and erodibility measurements, surficial measurements of total organic carbon chlorophyll *a* were made at a large number of sites within the southern Willapa Bay environment.

WORK COMPLETED

Activities during FY11 were threefold. First, the PI completed time-series field sampling that was initiated in November 2009 by conducting two additional 2-d sampling campaigns on the Willapa Bay mudflats, which resulted in a total of 9 sampling episodes over the year. Data collected during these field efforts consisted of replicate in situ resistivity (porosity) profiles (IRP) on D and C flats and in C channel and seabed samples for total organic carbon, seagrass shoot density, grain size, and chlorophyll-*a* (a proxy for exocellular polymeric substances). Second, processing of the IRP data and laboratory analyses of the TOC, chlorophyll-*a*, and grain size samples were completed in winter 2011. Third, the PI has been involved in the preparation of several publications (listed below) for a special volume of *Continental Shelf Research* and has served as one of the guest editors (with C. Nittrouer and B. Raubenheimer) for the volume.

RESULTS

Our understanding of the function of the Willapa Bay mudflats continues to evolve in several ways and illustrates the benefit of including a consideration of biological effects in studies of sediment dynamics. First, although there were clear seasonal differences in important forcings, such as insolation, rainfall, benthic microalgae and seagrass (*Zostera japonica*) abundance, these variations did not always result in measurable effects on seabed strength on the mudflats. For example, based on extensive theoretical and laboratory studies of seagrass, the extremely dense beds of the dwarf eelgrass that occur seasonally on the Willapa Bay mudflats (Fig. 1A) should have trapped fine-grained sediment at an accelerated rate and increased sediment porosity. In fact, measurements of grain size suggest this did not occur and IRP measurements indicate mudflat strength was steady throughout the year (Wheatcroft et al., in review). The likely reason for lack of an eelgrass effect is that late summer represents the driest part of the year when there was essentially no sediment being delivered from the uplands and no remobilization due to rainfall effects. This does not mean that seagrass have no importance in mudflat sedimentation, as other species have less pronounced seasonal variability in their above-ground biomass or they may have high shoot densities during periods of active sediment input and/or remobilization.

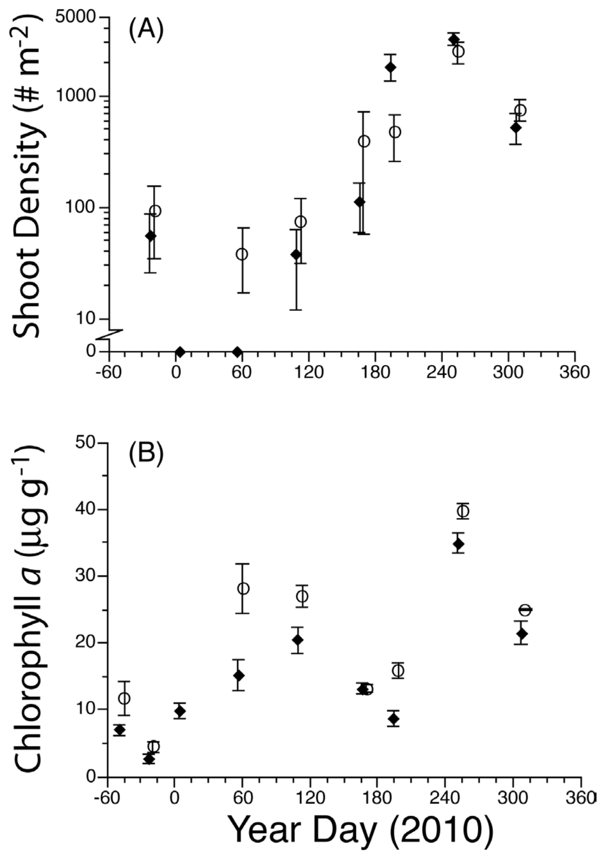

Fig. 1. A yearlong time series of two key biological variables measured on the Willapa Bay mudflats from November 2009 to November 2010 (C flat = open circles, D flat = filled diamonds; error bars are 1 SD). (A) Is shoot density (#/m^2) of the dwarf eelgrass, Zostera japonica, which varies from a low of 0 shoots/m^2 in the winter to a high of >3000 shoots/m^2 in late summer. (B) Is chlorophyll a content in mg/g dry sediment (a proxy for benthic microalgae), which shows low values in early winter and early summer, intermediate values in the late winter and spring, and highest values in late summer.

Another area of insight regarding physical/biological interactions involves the impact of microphytobenthos (MPB) or benthic microalgae on the erodibility of Willapa Bay mudflat sediments. Many previous studies have shown that the presence of MPB increases the critical shear stress for sediment (i.e., decreases erodibility); thus, we expected erodibility to be less during summertime. Results reported by Wiberg et al. (in review), however, indicate that there was no difference in winter-summer erodibility on the mudflats, which lacking MPB data seemed enigmatic. In fact, as shown in Fig. 1B there is a late spring-early summer decrease in MPB that is consistent with the erosion chamber results (i.e., measurements by Wiberg et al. were restricted to late Feb. and mid Jul. which had roughly similar MPB density). The likely reason for this fall off in MPB is enhanced grazing by macrofauna during this part of the year, which corresponds to the annual temperature maximum.

IMPACT/APPLICATIONS

In temperate mudflats, it may be that seasonal variation in important forcings, such as rain fall, solar input, and aquatic vegetation – all of which can be measured remotely – control the strength of the sediment. If this simple idea proves correct, then it may be possible to predict mud flat trafficability from known quantities.

RELATED PROJECTS

This effort is closely related to those of several other DRI investigators (see publication listed below). In particular, Pat Wiberg (U Virginia) provides measurements of sediment erodibility that are extended by my porosity measurements. Other collaborators are Paul Hill (Dalhousie U) and Brent Law, Tim Milligan (BIO) who are focused on determining patterns of sediment erosion and deposition mainly from a water-column perspective. Chuck Nittrouer (UW) is making independent measurements of seabed accretion and erosion, as well as documenting subsurface fabric. Lastly, the geotechnical measurements being made by Bruce Johnson (Dalhousie) extend and are enabled by my measurements of bulk density.

REFERENCES

Stevens, A. W., R. A. Wheatcroft and P. L. Wiberg. 2007. Seabed properties and sediment erodibility along the western Adriatic margin, Italy. *Continental Shelf Research* 27: 400-416.

Wheatcroft, R. A. 2002. *In situ* measurements of near-surface porosity in shallow-water marine sands. *IEEE Journal of Oceanic Engineering,* 27: 561-570.

PUBLICATIONS

Barry, M.A., B. D. Johnson, B. L. Law, B. P. Boudreau, R. A. Wheatcroft, V. Page, P. S. Hill. 2012. Sedimentary and geo-mecahnical properties of Willapa Bay tidal flats. *Continental Shelf Research*, (in review).

Law, B. L., T. G. Milligan, P. S. Hill, J. Newgard, R. A. Wheatcroft. 2012. Bed sediment texture on the Shoalwater Bay tidal complex, Willapa Bay: the role of flocculation. *Continental Shelf Research*, (in review).

Nittrouer, C. A., B. Raubenheimer, R. A. Wheatcroft. 2012. Lessons learned from comparison of mesotidal sand- and mudflats. *Continental Shelf Research*, (in review).

Wheatcroft, R. A., R. D. Sanders, B. L. Law. 2012. Seasonal variation in physical and biological factors that influence sediment strength on a temperate mudflat: Willapa Bay, Washington, USA. *Continental Shelf Research*, (in review).

Wiberg, P. L., B. L. Law, R. A. Wheatcroft, T. G. Milligan, P. S. Hill. 2012. Seasonal variations in erodibility and sediment transport potential in a mesotidal channel-flat complex, Willapa Bay, WA. *Continental Shelf Research*, (in review).